Sea Clutter Generation and Target Detection

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URSI 2007, North American Radio Science Meeting

URSI – CNC/USNC July 22-26 2007, Ottawa, ON

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

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Report Documentation Page

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1. REPORT DATE **2007**	2. REPORT TYPE	3. DATES COVERED **00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE **Sea Clutter Generation and Target Detection**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Illinois at Chicago,Department of Electrical and Computer Engineering,Chicago,IL,60607**	8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**25**	

Purpose

- Propagation model for the electromagnetic field that accounts for the clutter and metallic objects in the sea
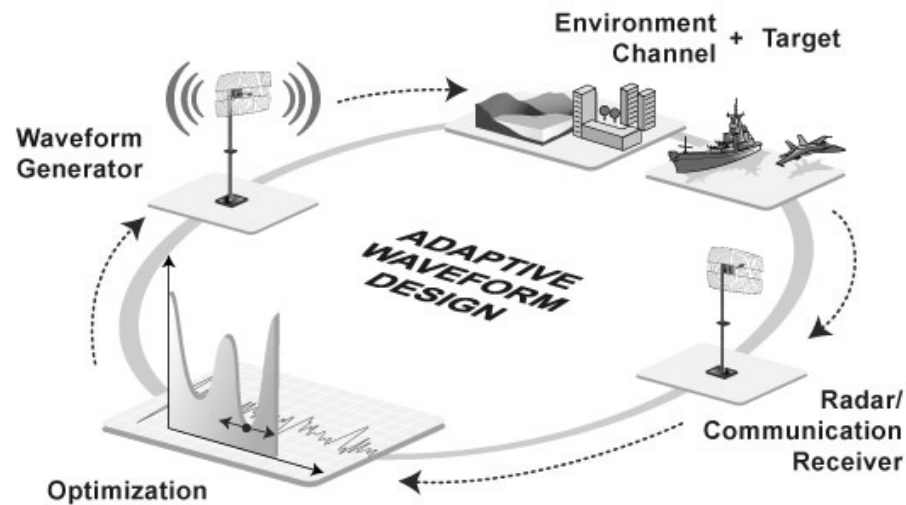

- Computationally fast
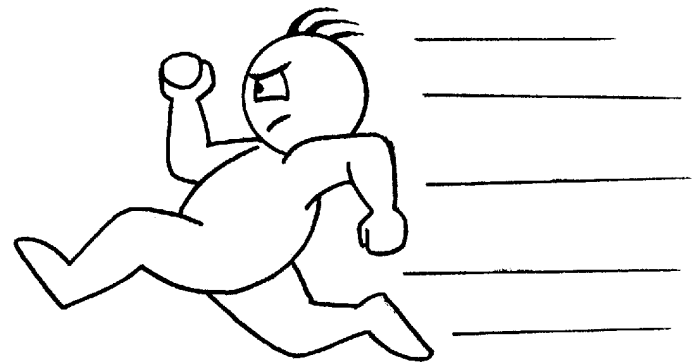
Purpose

- The complete work will include EM propagation models and vector antennas
- Support from U.S. DoD/AFOSR MURI and NRL/DARPA

Theoretical Background

- Stochastic models:
  - K-compound distribution
  - They take into account various aspects of the scattering process by sea waves

$$p(x) = \frac{2b}{\Gamma(\boldsymbol{n})} \left(\frac{bx}{2} \right)^{\boldsymbol{n}} K_{\boldsymbol{n}-1}(bx)$$

- Difficult to control the single physical quantities for wave generation

Theoretical Background

- Fractal deterministic models of the sea surface contain better physical modeling
  - Sea surface as a summation of an arbitrarily large number of wave contributions
  - Based on hydrodynamic models
  - Based on observation of quantities:
    - Wave velocity and direction
    - Wind velocity and direction
    - Multi-scalar description
    - Movement of target and observer

Contributions

- Geometry: 2D fractal model
- Electromagnetics: ray-launching
- Large scale problem ($> 5000\lambda$)

MoM
FDTD
Analytical Models
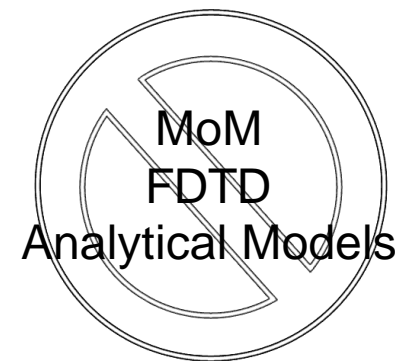
- Ray-tracing: good compromise between accuracy of the solution and computation time

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Contributions

- Better low-grazing incidence description

 - Cylindrical wave-front for radiated power
  - Multiple reflection
  - Scattering factors
  - Shadowing

Model

- Better control over the generation of the environment geometry
  - Wind speed and direction
  - Sea wave direction and height
  - Phase shift among different contributions
  - Evolution in time
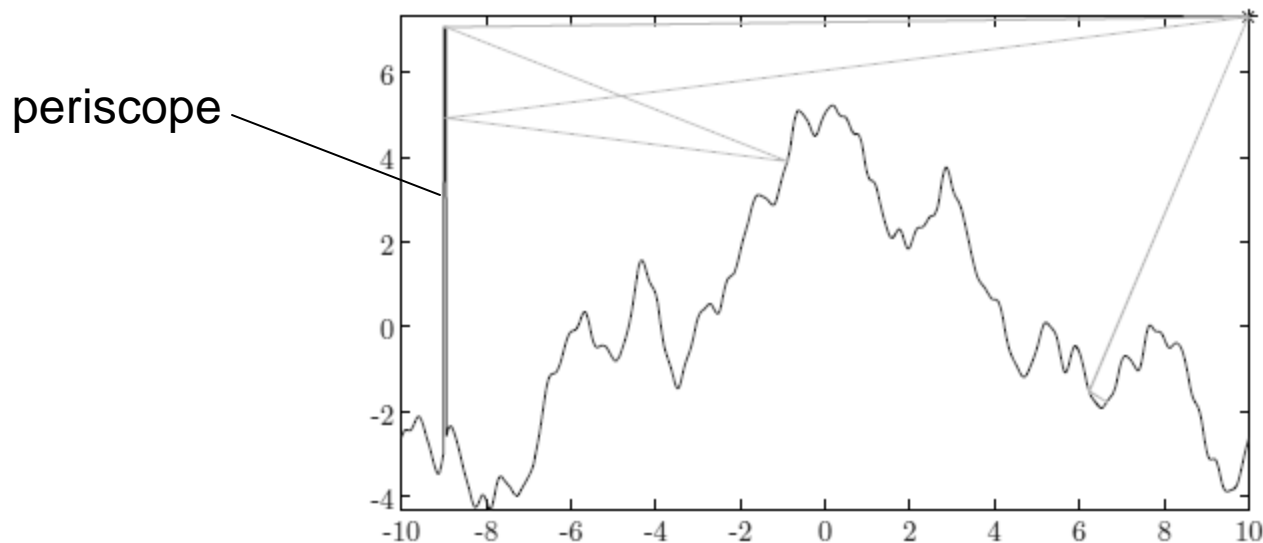 - Position and possible movement of an observer
- Based on hydrodynamics models

Assumptions

- Sea modeled as a lossy dielectric
- Multiple reflections over the sea surface
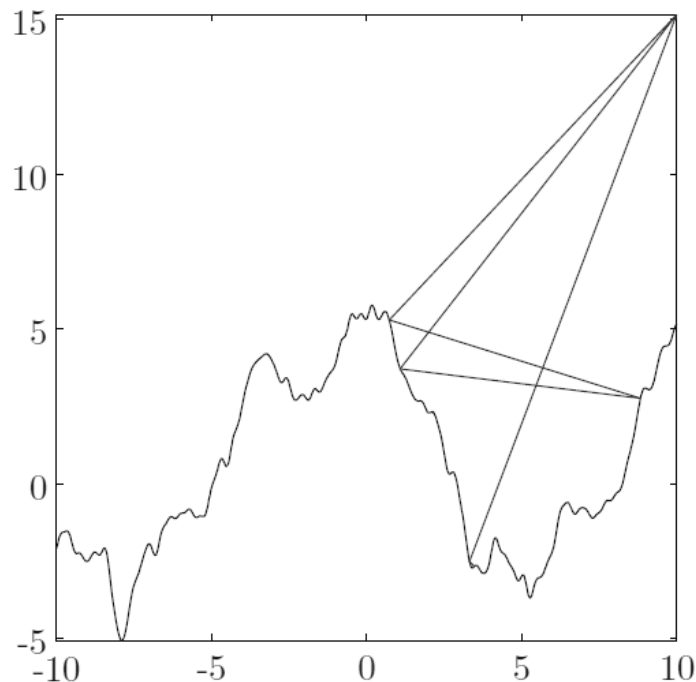
Assumptions

- Periscope: rectangular thin perfect conductor
- Reflections over the periscope walls and diffraction at the periscope edges

periscope

Assumptions

- We do not consider:
  - Transmission in the sea
  - Double diffractions on the periscope edges
  - Curved-element diffraction:
    - Sea water modeled as a dielectric
    - No whispering-gallery modes
    - High Losses

Validation in a Simple Case

- Very hard to acquire measured data
- IPIX: sampling rate too coarse for our model
- Military data not accessible
- Simple validation with FDTD method
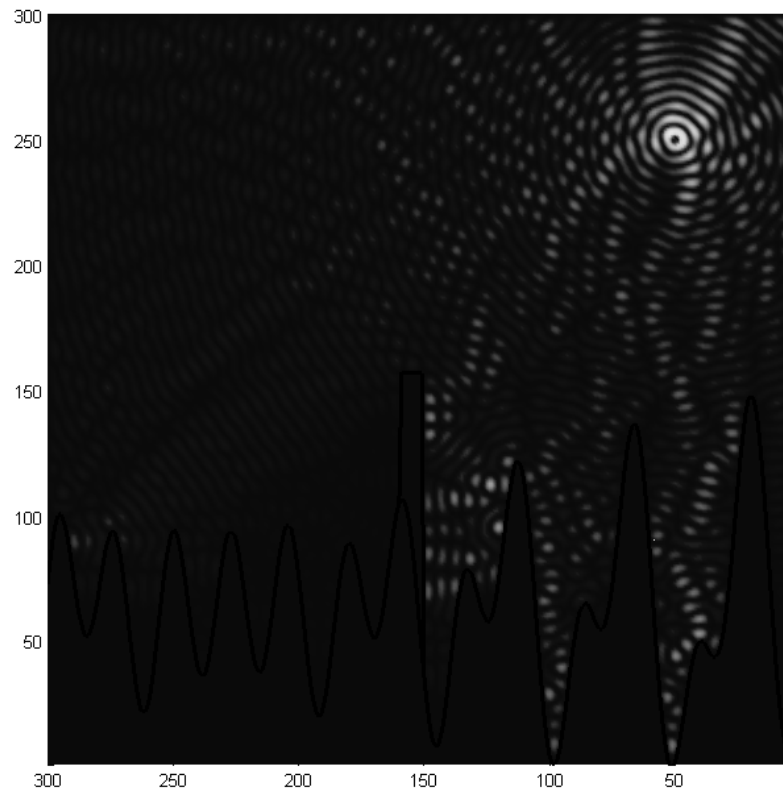 - Reduced surface
  - 30λ x 30λ

Validation in a Simple Case

- Differences:
  - Absence of curved-element diffraction
  - Double-diffraction
  - Instantaneous ray propagation vs. FDTD propagation

- FDTD Fourier Transform in test points is max ±1.5 dB compared to ray tracing

Validation in a Simple Case

Simulations

- TM and TE polarizations
- 2 different sea states, calm and high
- Different periscope heights that match the significant height of the waves
- Roughly 1750 different time instants
- 11 realizations of the sea evolving in time for each case
- Constant radar height when referred to the sea
- Fixed and floating periscope

Simulations

- The periscope is a tough object to detect
  - Thin object, easier to detect when tall
- The radar is usually located on a much higher location than the top of the periscope
  - No direct reflections are seen from the periscope
- Diffraction from the edges gives a small increment to the total measured field

State

- Standard deviation of wave height: 0.3m
- Height of the periscope: 3m
- Thickness of the periscope: 5cm
- Radar height: 20m
- The sea is at a relatively low state and the periscope oscillates on the sea surface
- The periscope is visible at short distances when the presence of the periscope is undisturbed by the sea
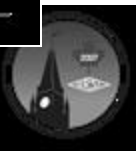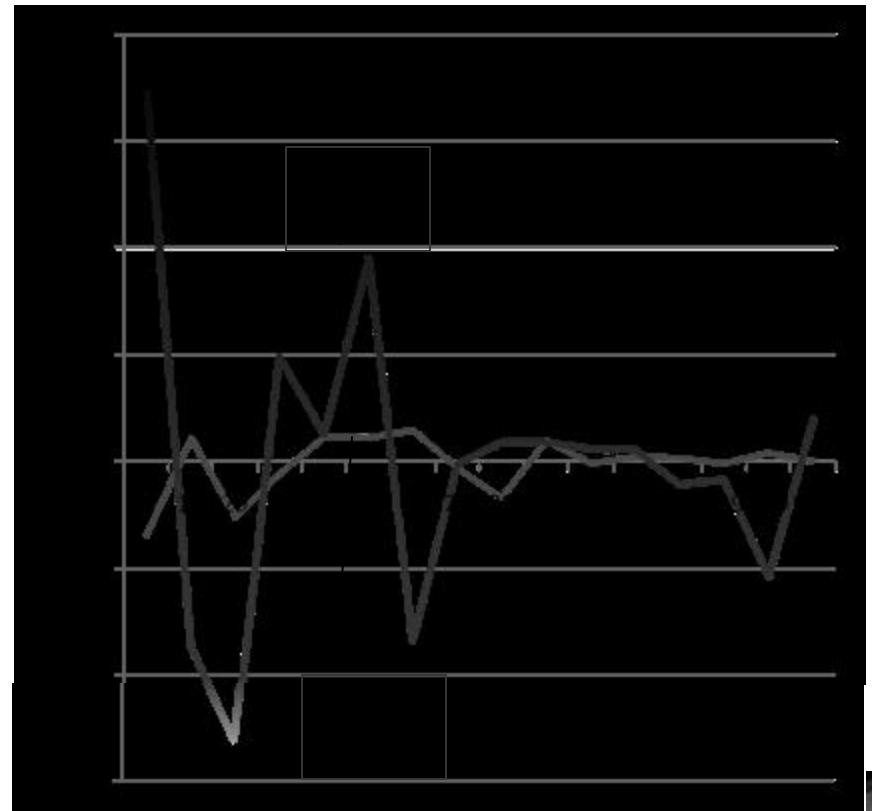- At larger distances, the periscope is mostly invisible to the radar
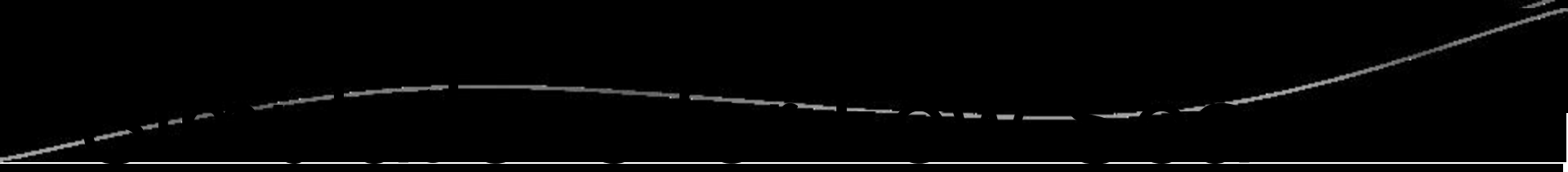
State

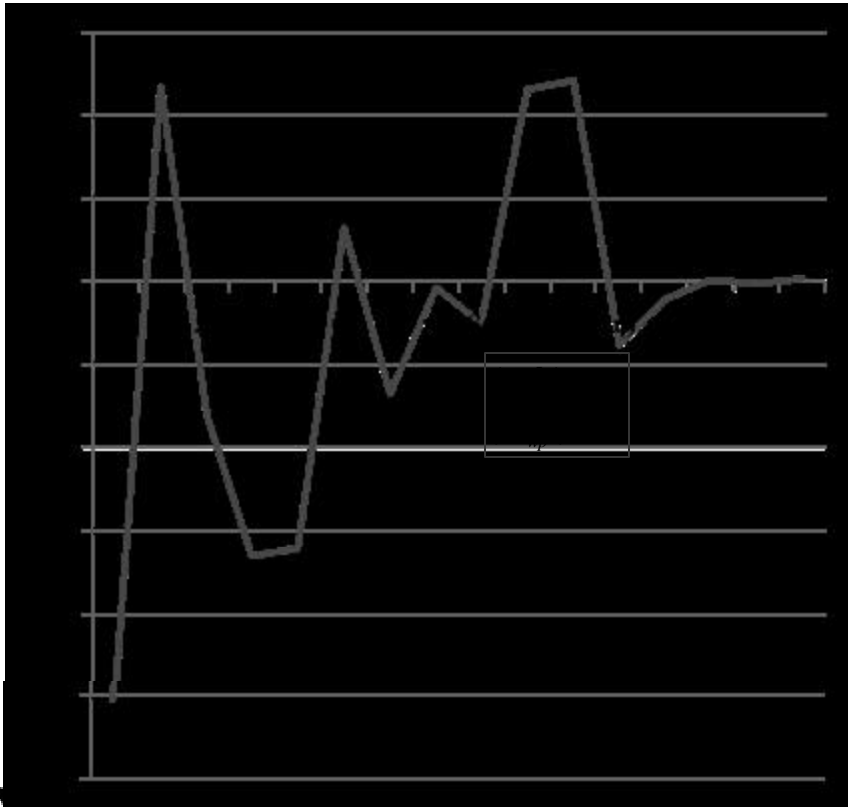**TE (H) pol.**   **TM (V) pol.**
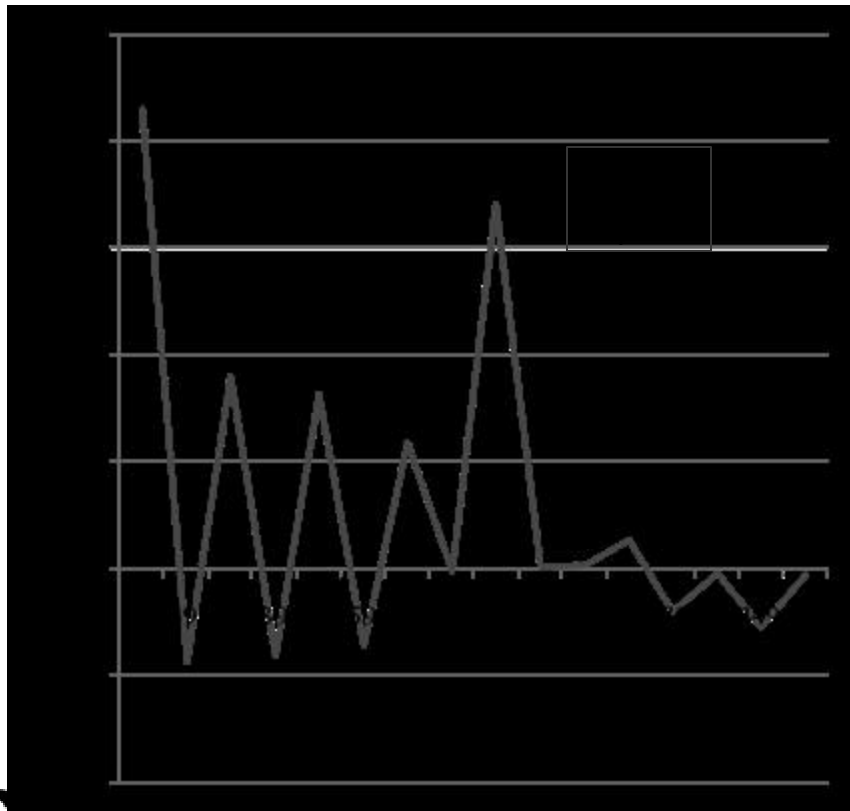
State

- Standard deviation of wave height: 3m
- Height of the periscope: 10m
- Thickness of the periscope: 5cm
- Radar height: 20m
- The sea state is very high and the periscope oscillates on the sea surface
- Counter-intuitively, oscillations in field ratios are very high
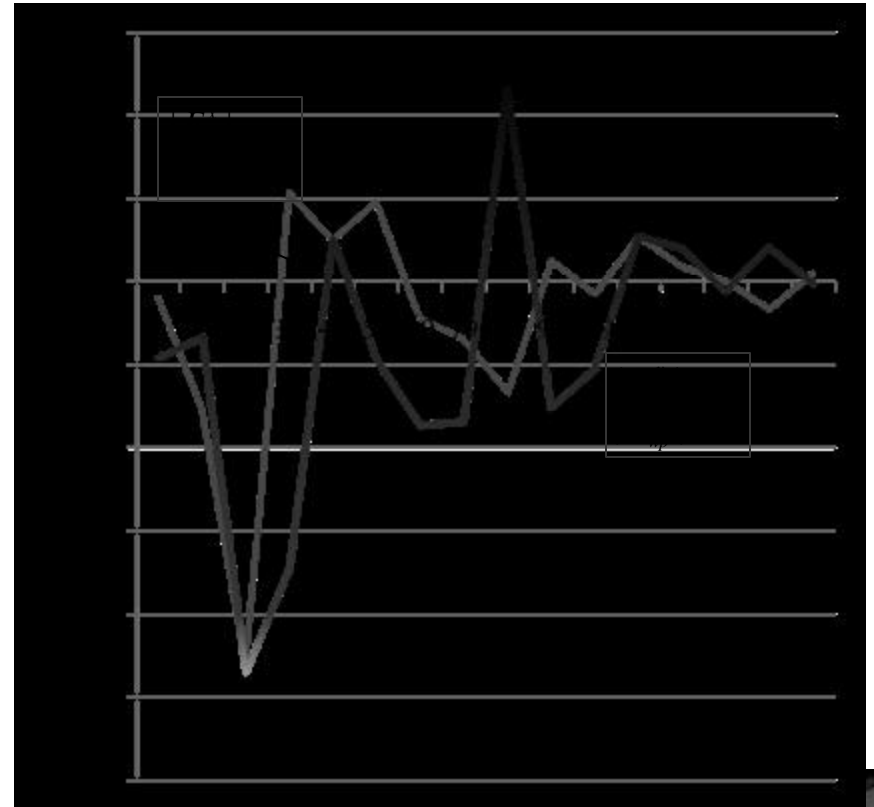 - The periscope has a direct effect on the return signal

State

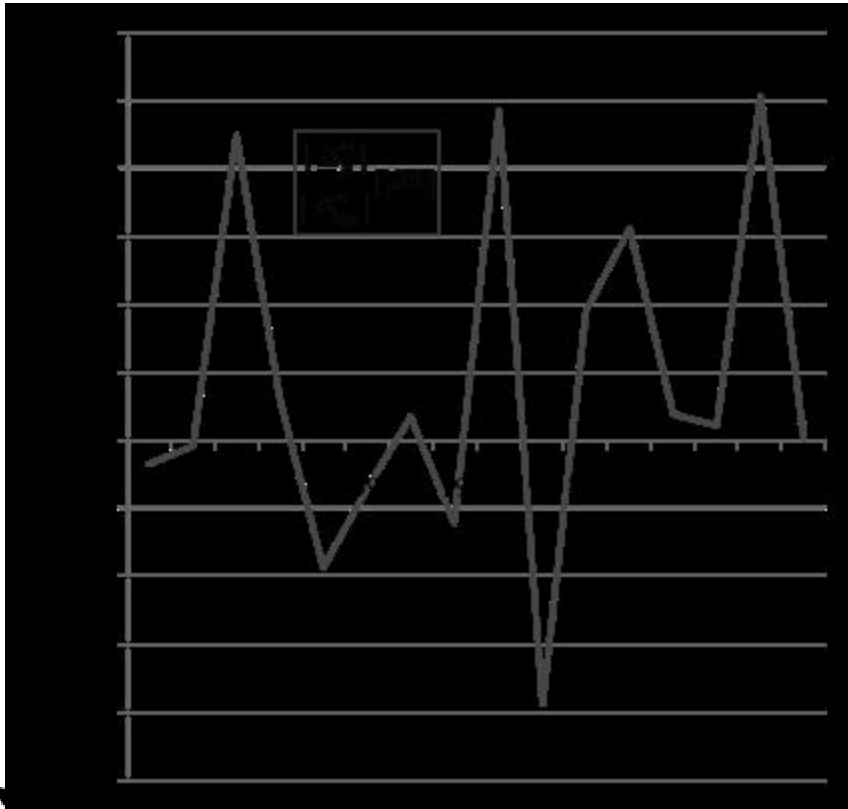**TE (H) Pol.**   **TM (V) Pol.**

State

- Standard deviation of wave height: 3m

- Height of the periscope: ~10m

- Thickness of the periscope: 5cm

- Radar height: 20m

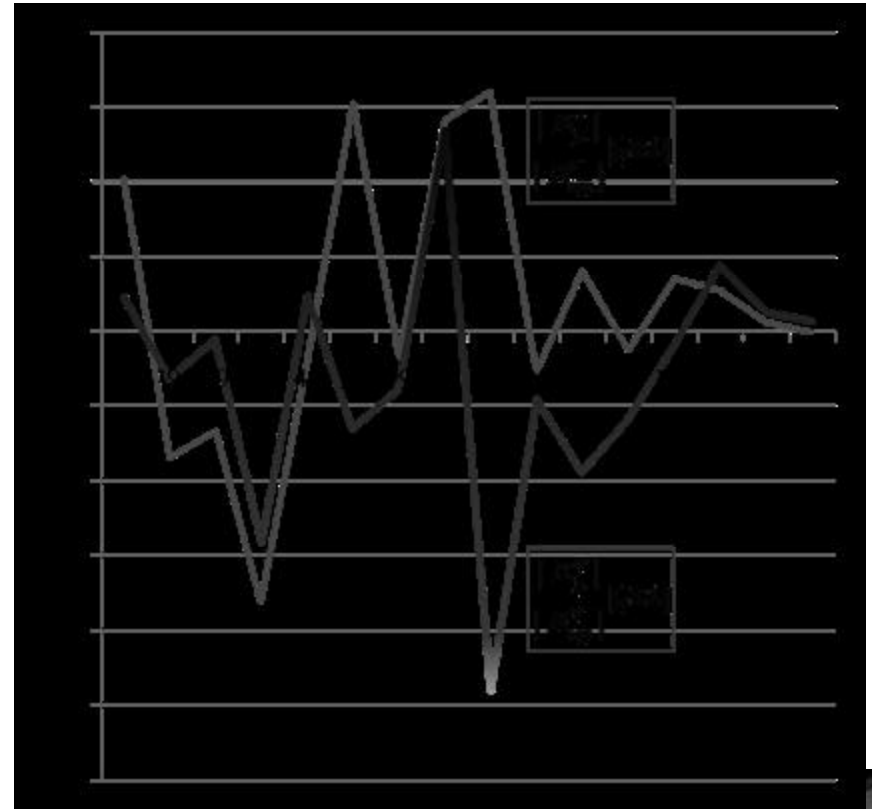- The sea level is very high and the periscope DOES NOT oscillate on the sea surface

State

TE (H) Pol.

TM (V) Pol.

Challenges in our Results

- Low sea state: the periscope is visible only at short distance
  - Only a few rays bounce back to the radar source
  - The sea is seen as a plate by the radar
- High sea state: the periscope is high
  - A significant amount of rays is bounced back
  - Large deviations in the measured fields

Future Development

- 3D fractal and ray-tracing model
- Run more simulations at higher distances and different sea states to determine the effect of the sea clutter
- Try to include diffraction by the sea
- Obtain measurement data (?)

Thank you!

Questions?